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Interactive comment on "Development of the Community Water Model (CWatM v1.04) A high-resolution hydrological model for global and regional assessment of integrated water resources management" *by* Peter Burek et al.

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Thank you for your review of our paper.

In this comment we report the reviewer's comments under <> , followed by our replies.

<The manuscript is not in the scope of GMD. The model concept (section 2.1) is described on 1.5 pages, and does not provide any insight into the modular model devel-

opment approach, which should be the focus in GMD. Thus, the novelty can not be assessed. >

We have now expanded upon our modular model approach in section 2.1, and have described in greater detail the modeling structure and why we think our manuscript is both relevant and worth publishing. The targeted audience of the model are hydrological modelers of varying levels of programming familiarity. Modelers with no experience in programing languages like Python can use the executable together with the settings file. Modelers with only limited experience in Python can use the platform-independent Python version with no need to adapt the code itself. Finally, modelers with programming capacity in Python can engage with the source code and adapt the model to their specific needs. The wide adoption of Python as a programming language and the open source approach will allow for a community of developers to engage with and further develop CWatM.

CWatM follows a modular development pathway in several ways which should help to simplify the use of the model for the different user groups. 1) The program itself is independent from the settings file, which includes all relevant information of data, parameters for each process and output options. This enable the user to run the model without any understanding in Python and the users has a lot of flexibility to choose input data and output options. 2) The hydrological processes are modules separate modules from those related to data handling (e.g., reading configuration, reading and writing routines, error handling) and has individual modules for each hydrological process group (from the calculation of potential evaporation to river routing). This enables the advanced user to concentrate on developing their own hydrological modules. 3) In addition, each module is identically composed of an initialization class and a class which is run during the time steps. 4) CWatM keeps track of the metadata on sub routine of the source code and of data. It uses netCDF4 format as in- and output to store temporal-spatial data efficiently and to use meteorological forcing data as they come without reformatting. NetCDF4 also has the advantage that metadata are directly attached to the data. 5) In order to reach its community, CWatM comes with an online documentation on https://cwatm.iiasa.ac.at/, which includes the basic steps to setup the model, the data structure, the license information and uses Sphinx for auto-documentation of source code.

A major goal of the model is to link it to other models (see section 5.5.3). A modular structure is easier to maintain and can support a better interaction with these models. We have now expanded upon section 5.5.3 into section 6. Now called "Linking and integration with other sectoral models", we describe how the modular structure of CWatM can support better integration with other models, such as ECHO, MARINA, MESSAGE, GLOBIOM. We hope that this more accurately shows that the model takes care of using best practice in research software as stated in Wilson et al., 2014 and Jiménez et al., 2017. CWatM is already used in several scientific assessments including Wang et al., 2019a, Wang et al., 2019b, He et al. 2019, Vinca et al., 2019, Kahil et al. 2019.

< The theoretical descriptions of the hydrologic processes do not contain any new theoretical development. The data sets used by the model are open and standard. The applied calibration procedure is also standard. >

The utility and relevancy of our model is in its possible integration with other models and sectors, the capacity to model at multiple spatial scales, and its capacity to foster a community of use and development. Several hydrological processes are relatively new including preferential flow pathways, the timing of runoff concentration, and the urban extent as an independent land cover class. The hydrological processes and combination of systems are modeled according to referenced literature. The data sets are necessarily open and standard to comply with open source practices. The calibration is standard, but also flexible and adaptive. The model is thus offered as a package both immediately useable and adaptable. At the moment only WaterGAP is calibrating their model. We see the need (shown in Fig 8) to properly calibrate the model and even go for a globally calibrated model. We appreciate the comment and have expanded the discussion section 2.1.

< The results section does not allow any conclusion about the utility of the model >

To highlight some aspects of section 5, we provide examples of where the model has been applied in conjunction with water quality and hydro-economic modeling, with case studies and results for both the extended Lake Victoria basin the Zambezi basin. Further we highlight that CWatM has been applied for different purposes (Wang et al., 2019a, Wang et al., 2019b, He et al. 2019, Vinca et al., 2019, Kahil et al. 2019). We appreciate the comment and have expanded upon the discussion by shifting section 5.5.3 into section 6 to better underline the linkage to other models and results.

< The input timing for the meteorologic information for a regional model does not lend confidence in the software development approach>

We are currently using a daily timesteps with daily meteorological forcing data. The model is also using daily sub-time steps where required e.g. the percolation in the soil and the routing, as well as the lake and reservoirs module uses sub-steps. For soil this is already in: "Therefore, the soil moisture equation has to be solved iteratively on a sub-daily time step." For river routing we have added: As water can travel a distance greater than a cell size in one day, river routing and the lake and reservoir routines are performed on a sub-daily time step, based on the chosen spatial resolution. The spatial scale we are using at the moment is 5 arcmin to 30 arcmin. Even models dealing with flood forecast on European level with a spatial resolution of 5x5 km2 (Lisflood in the European Flood Awareness System https://www.efas.eu/en/overview) are using daily time steps. We are aware that if we using a spatial resolution of 1 km2 (like in our project in India https://fuse.stanford.edu/hydrology-and-water-resources) and dealing with flooding or even flash-flood we have to go down in timely resolution as well, but at the moment we work on water availability, water demand with daily available climate projections. ———————————————————————————————

< The global water balance is not sufficient to demonstrate the utility of the model, There is much more information available to convince the reader of the usefulness of the proposed model. For example, Scanlon et al. (2018) posed a challenge for global hydrologic models to simulate correctly the water storage trends globally.>

We are aware that several papers and models use either observed discharge stations or GRACE to evaluate the global results of their models (see below for a list). For sure we can produce maps which shows some agreement between simulation and measurement but: 1) exactly the paper you mention Scanlon et al. (2018) points out that the used models show a "poor agreement between models and Grace" and to show some results for a single model might be not a real prove. 2) we think that it is best practice to show the performance of a model is in the framework of an intercomparison project in comparison with other models. As our model is quite young (one reason to have this manuscript here) we are not part of the study in Scanlon et al. (2018) but we are already part of Inter-Sectoral Impact Model Intercomparison Project (ISIMIP), and upcoming publication will include results from CWatM e.g. from Yadu Pokhrel et al. on global terrestrial water storage. This includes also a fair and independent comparison of GRACE and model results from seven global hydrological models.

Further on we showed in fig 8 that especially in data sparse regions uncalibrated results from different models can be quite wrong (also CWatM) and calibration or fitting is necessary. This is shown only for a single station to illustrate that, but if necessary several other stations can be shown. This is a different view of evaluation than showing global maps of correlation or other indicators but shows also some shortcoming of global models (and of CwatM). We appreciate the comment and the reference to Scanlon et al. (2018), and we are working on furthers comparisons for future work. We have added this comment into the manuscript: Some modeling papers such as

Döll et al., 2014 and Sutanudjaja et al., 2018 use observed discharge stations or the Gravity Recovery and Climate Experiment (GRACE) Tapley et al., 2004 to evaluate the global results of their models. As CWatM has started to be part of the ISIMIP inter-comparison project, we evaluated that it is best practice to show the performance of a model in the framework of ISIMIP by comparing it to other models like in Zhang et al., 2017 or Scanlon et al., 2018. An upcoming paper by Pokhrel, 2019 on global terrestrial water storage will include a comparison of seven global terrestrial hydrology models (including CWatM) against GRACE data.

<The calibration results show that the calibration works, which would be surprising if not (are the parameters calibrated at each pixel?)>

The idea of showing calibration here is to show that it works. Most scientific papers show a method and shows afterward to what extent it works. Parameter are calibrated on sub-basins (for Lake Victoria and Zambezi). We have added this line in 5.5 to account for that: Calibration is performed for three stations. The calibration parameters are valid for the sub-basin up to the gauging station. The upstream station is calibrated using the best fit of the downstream calibrated sub-basins. Calibration for the Zambezi basin is performed for six stations (Lukulu, Kongola, Katima, Kafue Hook, Luangwa Road Bridge, Tete - see figure 6). The calibration parameters are valid for the sub-basin up to the gauging station. The upstream station is calibrated using the best fit of the downstream calibrated sub-basins. The parameter set is valid for the sub-basin exclusive of the downstream sub-basins which have their own parameter set.

<But what about validation?>

Validation of calibration results are show in the supplement. We added a line to refer to the supplement for validation.

<While section 5.4 presents perhaps meaningful results, they are not suitable for GMD.> <In addition, there is much more to community model development than the term and providing the code in a git plus documentation. I encourage the developers to study principles of best practices for community scientific software development and think about a software productivity and sustainability plan>

In fact there is a lot more than providing code and documentation. We take this point and show in section 2.1 that we include some more ideas based on established examples such as the Community Land Model (Lawrence et al. 2018) or the mesoscale Hydrologic Model (Samaniego et al. 2019). Several aspects of our supports the user and development, incorporating good practices for scientific software development, such as code management, documentation with a tutorial, and automated documentation. We already have users in China, Europe, Japan, India, and other countries, so there exists the demand for a model like CWatM. Some parts are still under development and can be improved like our forum on https://cwatm.iiasa.ac.at/forum.html where users can help each other. The fact that we do not have a full set "software productivity and sustainability plan" is because we are at the point of establishing our model and one part of this is to publish our model at a journal which promote an open research culture like GMD. But we use this comment to extend section 2.1. For sure there is still a lot to do to reach a high standard like improving software management by building up an automated testing, easier installation via the Python Package Index and building containers and improving the communication with the users via an improved forum.

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